10 Mb/s Single Twisted Pair Ethernet

Powering in an Intrinsically Safe System

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Overview

Supporting Presentation for Objective:

Specify an optional power distribution technique for use over the 10 Mb/s single twisted pair link segments in conjunction with 10Mbps single-pair PHYs.

Content:

- Principle of Intrinsic Safety
- Assessment of intrinsically safe Circuits
- Reference Curves and Tables
- Allowed Energy Storage (C and L)
- Energy Storage within Cables
- System Structure
- Trunk and Spur Cabling
- Example: Spur Circuit
- Example: ispark (PTB Calculation Tool)
- Powering Examples

Principle of Intrinsic Safety

Associated apparatus (e. g. power supply):

Maximum output voltage U_o
Maximum output current I_o
Maximum output power P_o
Maximum allowed external inductance L_o
Maximum allowed external capacitance C_o

Cable:

Inductance per unit length $L_C{}'$
Capacitance per unit length $C_C{}'$
Resistance per unit length $R_C{}'$

Intrinsically safe apparatus (e. g. field device):

Maximum input voltage U_i
Maximum input current I_i
Maximum input power P_i
Maximum internal inductance L_i
Maximum internal capacitance C_i

Assessment for intrinsic safety:

$U_o \leq U_i$
$I_o \leq I_i$
$P_o \leq P_i$
$L_o \geq L_i + L_C{}'$ * cable length
$C_o \geq C_i + C_C{}'$ * cable length

If the external inductance as well as the external capacitance of the connected equipment are > 1 % of the specified values, the specified values of L_o and C_o shall be reduced to 50 %.

Assessment of intrinsically safe Circuits

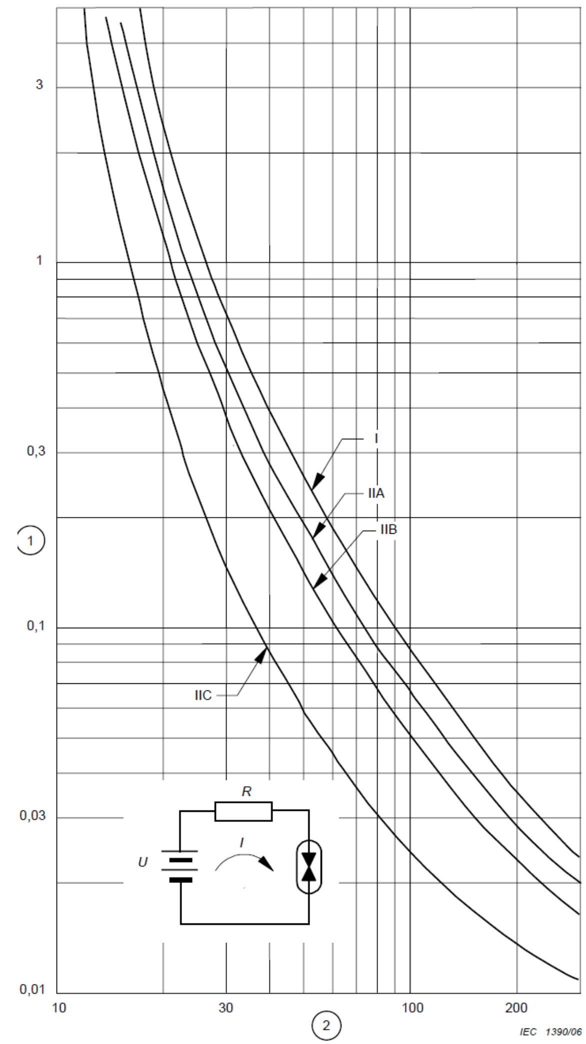
- The relevant ignition curves and tables to meet the requirements of intrinsic safety are provided in IEC/EN 60079-11 standard in Annex A.
- In this annex curves for resistive, capacitive and inductive circuits are given.
- These curves provide the maximum possible values before an incendive spark occurs.
- For Ex ia/ib a safety factor of 1.5 has to be applied to the voltage, current and power.
- Unfortunately there is no easy method for the calculation of mixed (R, L, C) circuits given within the standard.
- The provided data within the standard can be used to get a rough estimation, nevertheless when trying to get the maximum possible values, other methods are needed to assess such circuits.
- In principle there currently exist two methods:
  - Using a spark test apparatus and doing practical tests (the DUT is connected to a spark test apparatus with a gas mixture being provided within a small explosion chamber; within this chamber sparks using a cadmium plate and a tungsten wire are created using a rotating mechanic and as long as there is no explosion caused, the circuit is assessed to be safe).
  - Using a software as „ispark“ from PTB, which is able to calculate the possible values for such circuits. The software is an easy way to calculate mixed circuits and even include cable parameters within the calculation, nevertheless the values provided by the software as some percent lower what could be reached by testing.

Reference Curves and Tables

- The reference curves provide values for different gas groups (IIA, IIB, IIC) and mining applications (I).
- The difference between these gas groups is the required energy causing an ignition.
- Gas group IIC (e. g. Hydrogen) is the most critical group, nevertheless most equipment is certified for IIC, because this allows the highest flexibility.
- The resistive curves or tables always provide the maximum possible current values; if there are more complex circuits, which are not just resistive, but contain energy storage elements or cables the maximum permitted output current of a source is lower.

Voltage V	Permitted short-circuit current mA							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
17	800	533	2 000	1 340	2 830	1 890	3 480	2 320
17,1	780	523	1 960	1 310	2 760	1 840	3 450	2 300
17,2	770	513	1 930	1 280	2 700	1 800	3 420	2 280
17,3	750	503	1 890	1 260	2 630	1 760	3 390	2 260
17,4	740	493	1 850	1 240	2 570	1 720	3 360	2 240
17,5	730	484	1 820	1 210	2 510	1 680	3 320	2 210
17,6	710	475	1 790	1 190	2 450	1 640	3 300	2 200
17,7	700	466	1 750	1 170	2 400	1 600	3 260	2 170

IEC/EN 60079-11, Table A.1



Key

1 Minimum ignition current I (A)   2 Source voltage U (V)

Allowed Energy Storage (C and L)

- Additionally to a resistive power limiting, as shown on the previous slide, also a limitation of the stored energies within an intrinsically safe system is required.
- The minimum ignition energy when doing spark testing acc. to IEC/EN 60079-11 for gas group IIC is 40 µJ.
- Detailed information about the maximum allowed capacitance at a given voltage are provided in IEC/EN 60079-11, Table A.2. In this table also values including the safety factor for Ex ia/ib are stated.
- Due to the freewheeling effect of an inductance the maximum allowed energy within an inductor will never be higher than 40 µJ. For Ex ia/ib an additional safety factor of 1.5 for the current and 2.25 for the energy has additionally to be taken into account.
- If the energy within an inductor is higher than the allowed values, it has to be clamped with free wheeling diodes, to prevent the appearance of a high inductance voltage.
- In mixed R, L, C circuits the calculation of the maximum allowed capacitance or inductance is more complex and has to be tested or calculated with an appropriate software.

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
17,5	1,56	0,339	10,5	1,97	42	8,2	44	11,2
17,6	1,53	0,333	10,2	1,93	40	8,1	42	11
17,7	1,50	0,327	9,9	1,88	39	8,0	40	10,64
17,8	1,47	0,321	9,6	1,84	38	7,9	39,2	10,48
17,9	1,44	0,315	9,3	1,80	37	7,7	38,6	10,16
18,0	1,41	0,309	9,0	1,78	36	7,6	38	10
18,1	1,38	0,303	8,8	1,75	35	7,45	37,3	9,86

IEC/EN 60079-11, Table A.2

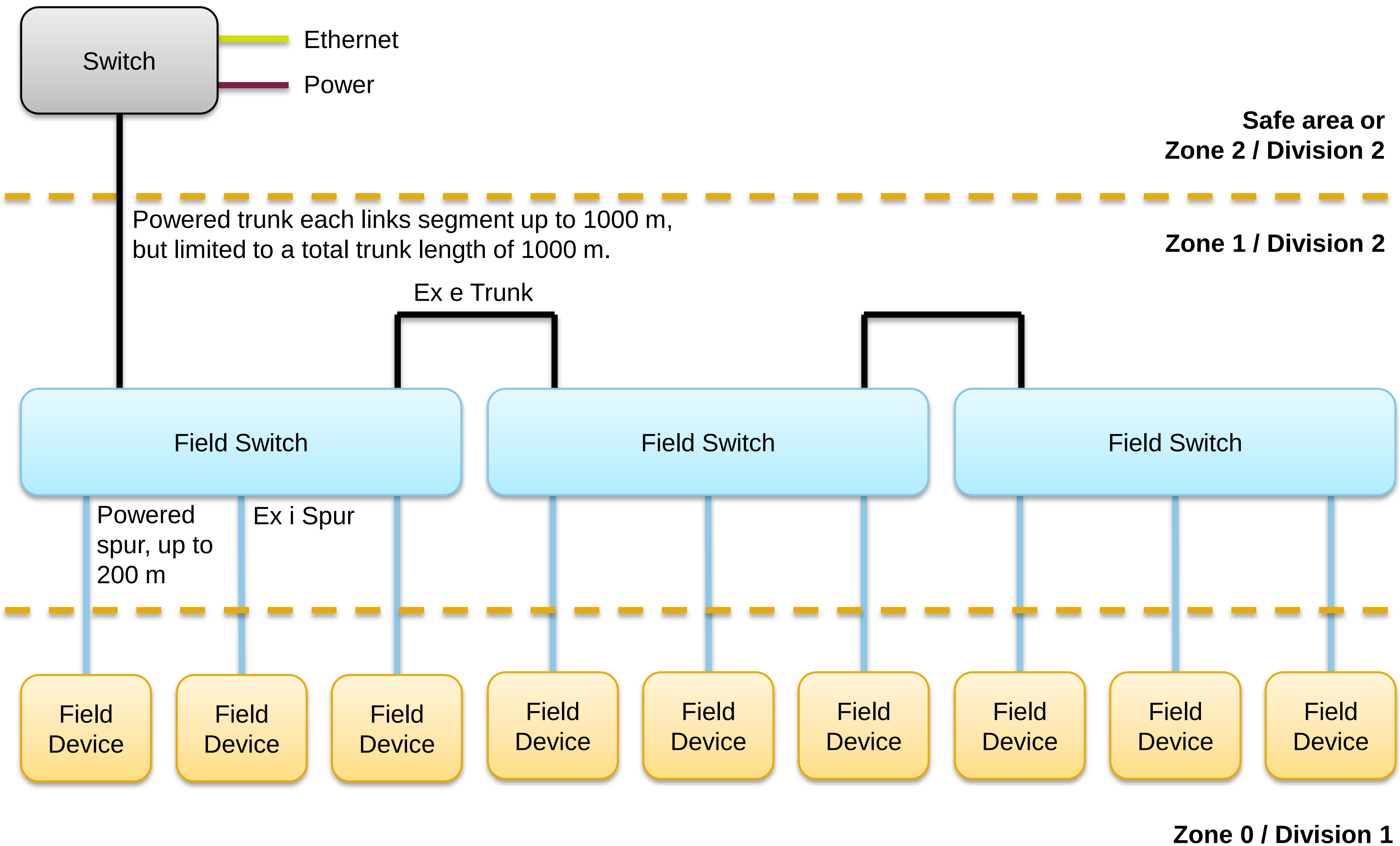
Energy Storage within Cables

- Assuming, that the internal capacitances and inductances within the intrinsically safe supply are negligible, the maximum allowed L_o/R_o ratio of a cable to stay within the safe range can be calculated with the following formula:

  $L_o / R_o = 32 * 40\ \mu J * R_S / (9 * U_o^2)$

- R_S is the minimum output resistance of the intrinsically safe power supply.
- The formula already includes the necessary safety factor.
- More details can be found in IEC/EN 60079-11:2011, chapter 6.2.3.

System Structure

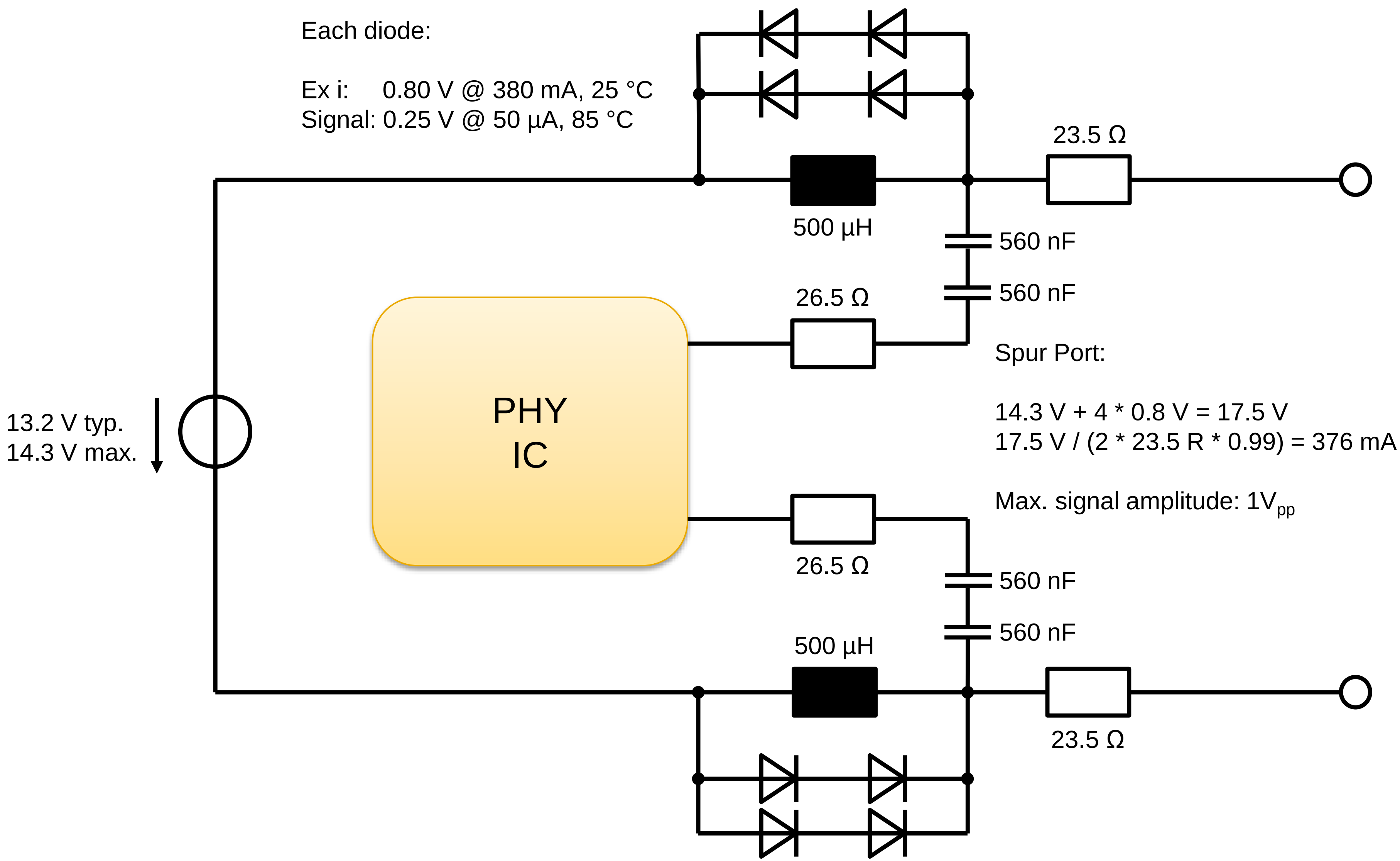


Trunk and Spur Cabling

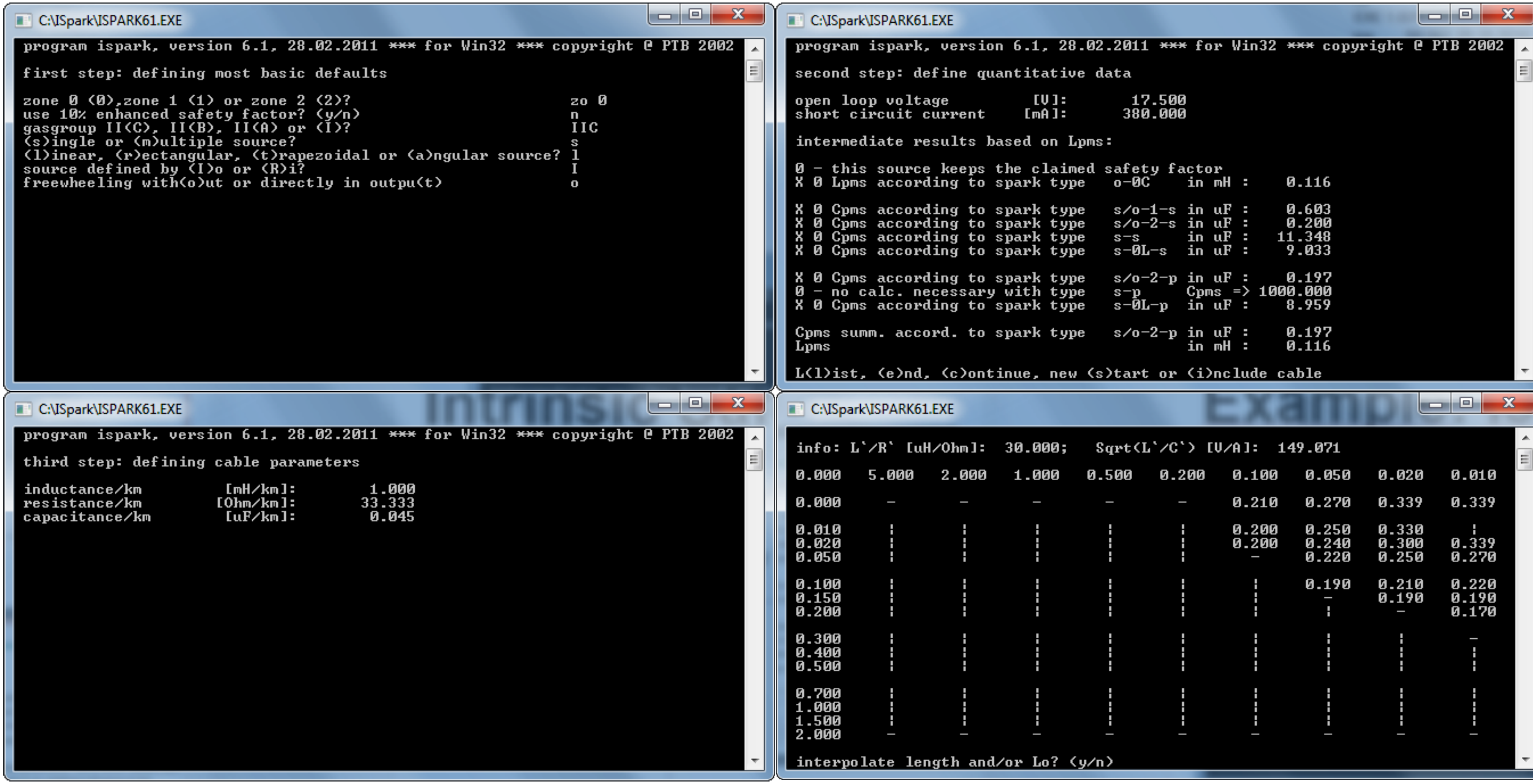
- **Trunk cabling:**
  - A maximum trunk cable length of 1000 m is required for process industry applications.
  - Preferred hazardous area protection method for a powered trunk is increased safety (Ex e).
  - Hazardous area protection methods for a non-powered trunk can be increased safety (Ex e) or intrinsic safety (Ex i).

- **Spur cabling:**
  - A maximum spur cable length of 200 m is required for process industry applications.
  - Preferred hazardous area protection method for a spur is intrinsic safety (Ex i).

Example: Spur Circuit



Example: ispark (PTB Calculation Tool)



- Input: U_o = 17.5 V, I_o = 380 mA, L_C' = 1 mH/km, R_C' = 33.333 Ohm/km, C_C' = 45 nF
- Result: L_o = 10 µH, C_o = 170 nF @ 200 m cable

Powering Examples

- Powering options for non-Ex applications, Ex e (increased safety) and Ex i (intrinsic safety).
- The following tables gives technically possible example values for Ex ia/ib spur power values and Ex e trunk power values.

Parameter (Ex ia/ib)	Value
Maximum output voltage U_o	17.5 V
Maximum signal voltage	1.0 V_{pp}
Inductor clamping voltage	3.2 V
Maximum allowed supply voltage	14.3 V
Overvoltage limitation	14.0 V ± 0.3 V
Functional supply voltage	13.2 V ± 0.3 V
Short circuit current I_o	380 mA
Minimum output voltage	9.6 V
Minimum device voltage	9.0 V
Maximum device current	55.6 mA
Maximum available device power	500 mW
Maximum allowed inductance L_o	10 µH + cable *)
Maximum allowed capacitance C_o	5 nF + cable *)

Parameter (Ex e)	Value
Maximum functional supply voltage	48.0 V
Maximum supply voltage for Ex e	52.8 V
Minimum functional supply voltage	24.0 V
Minimum supply voltage for Ex e	21.6 V
Maximum supply current	1.25 A (tbd.)

*) 10 µH/5 nF per field device, up to 200 m spur cable.

Possible cable parameters:

R_C = 15 Ω/km … 150 Ω/km
L_C = 0.4 mH/km … 1 mH/km
C_C = 45 nF/km … 200 nF/km
$L_C / R_C \leq 30$ µH/Ω

- Depending on other use cases there will be several other power profiles, which need to be defined.

Thank You